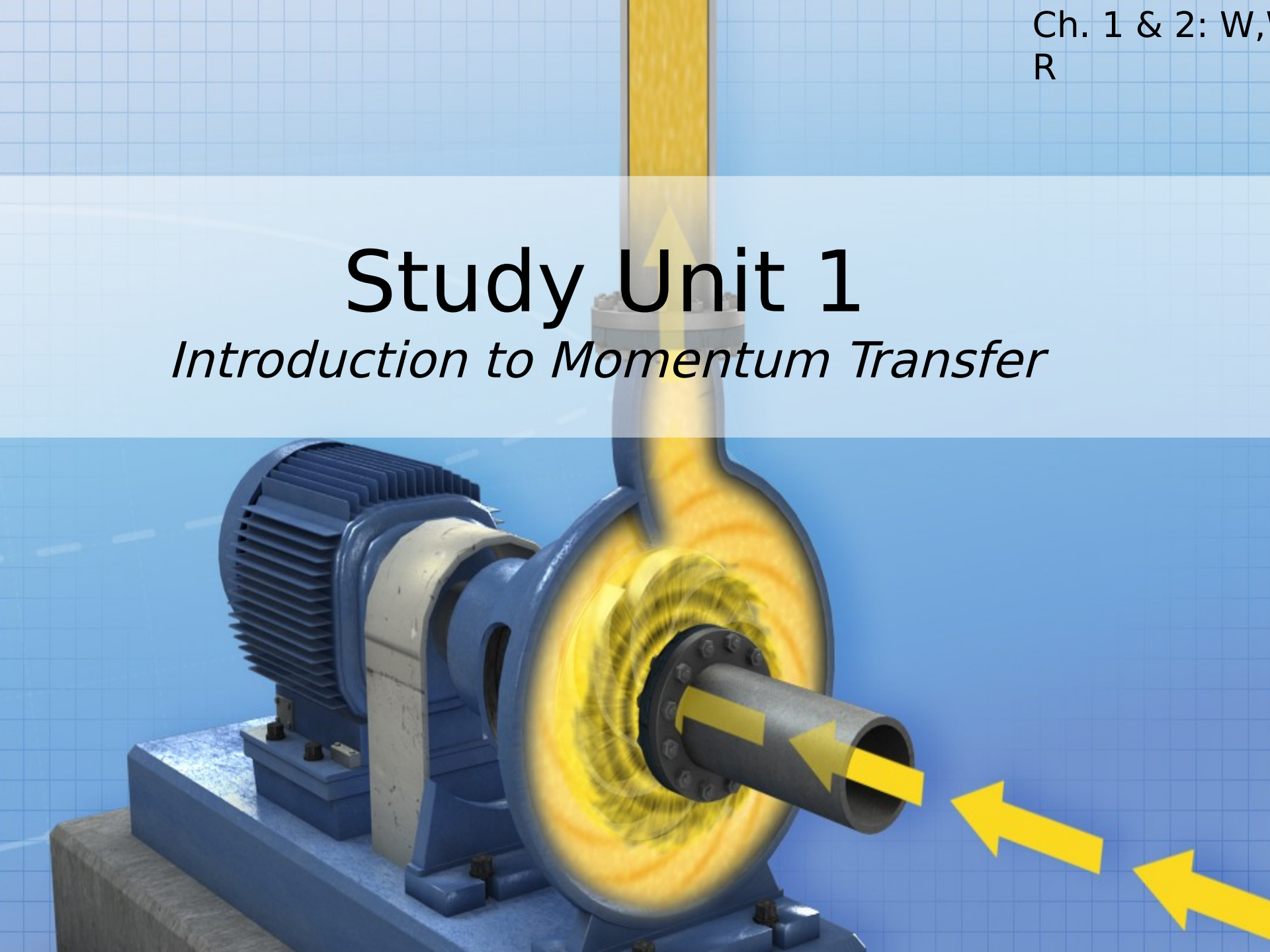
Ch. 1 & 2: W,
R

Study Unit 1

Introduction to Momentum Transfer

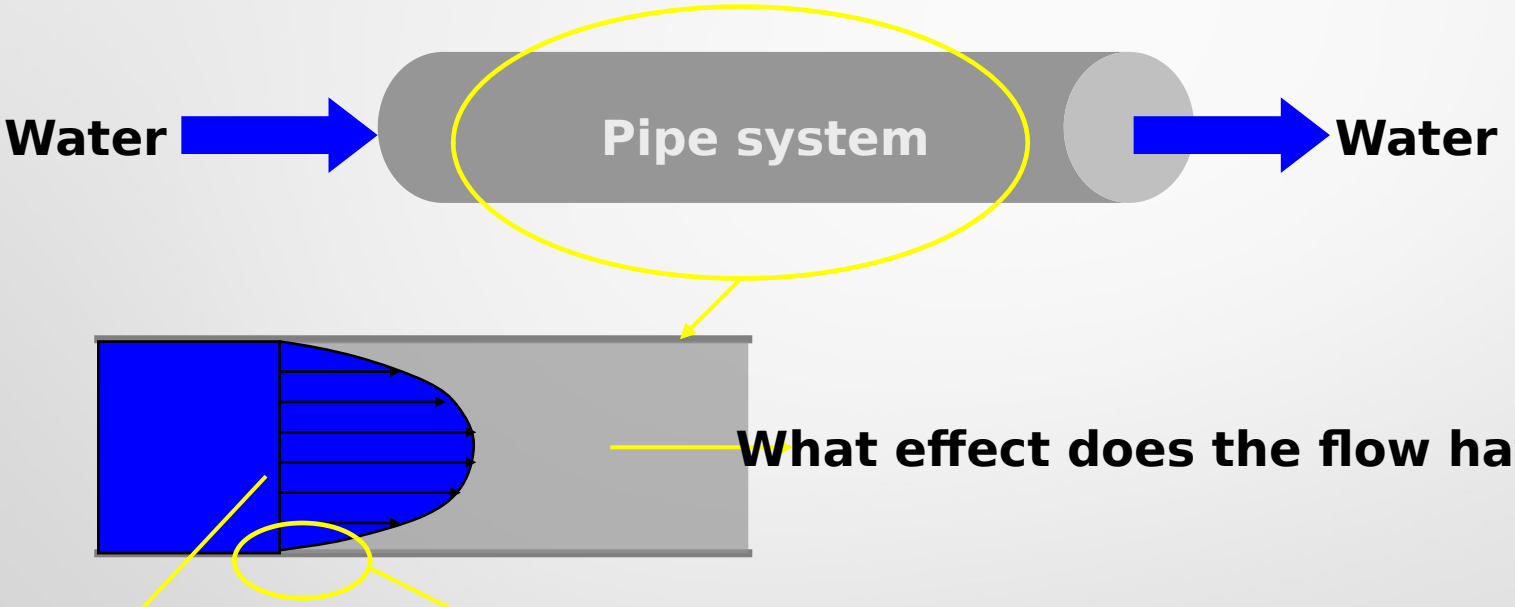


Outcomes

- Understanding the concepts and definitions regarding momentum transfer;
- Understand the concept of flow properties at a point;
- Understand & describe the Point-to-Point variation of properties in a fluid;
- Formulate and describe pressure variations in a static fluid;
- Describe the forces on submerged surfaces and apply the general concepts of fluid statics.

General

- What is momentum transfer (fluid dynamics)?

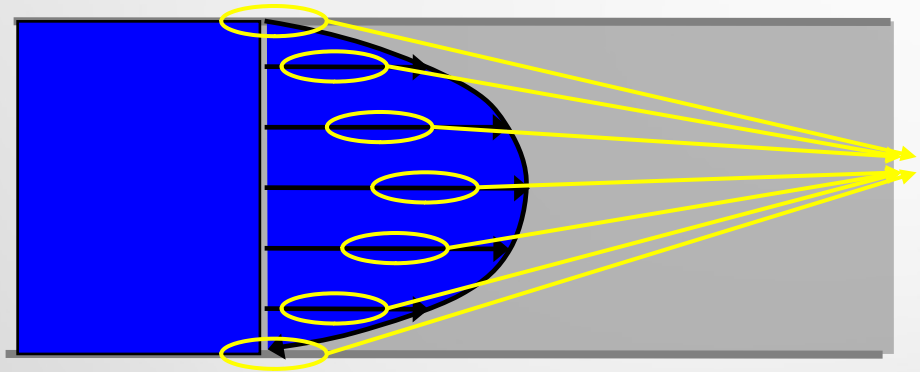


THUS, THE STUDY OF:

FLUID MOTION & EFFECTS

1.1. Fluids & the continuum (1)

- Momentum transfer studies fluids.
  - Fluid: substance that deforms continuously under the action of shear stress.

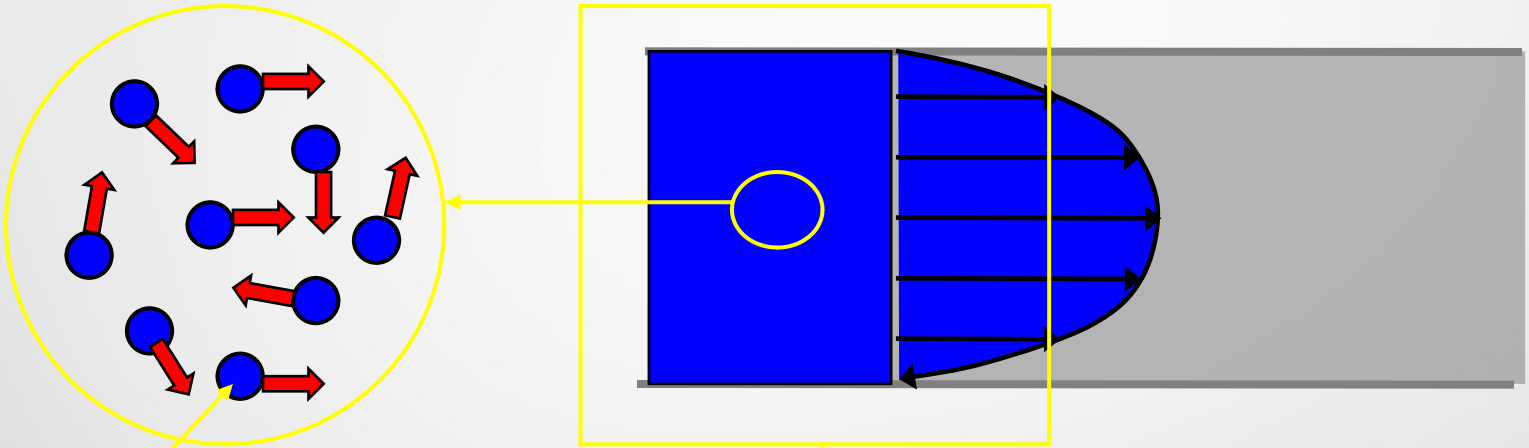


Shear stress: Friction between levels/ layers

  - Fluid in rest: no shear stress.
  - Different fluids: gasses & liquids.

1.1. Fluids & the continuum (2)

- What is a continuum?



Difficult to describe a single molecule.

Refer to Fig 1.1 and 1.3 in the textbook

Engineering application: Macro- explanation

Continuous distribution of matter

1.2. Fluid properties at a point (1)

- In a fluid the macroscopic properties vary continuously from point to point.
  - Fluid & flow properties:
    - Gas = compressible while liquid ≠ compressible.
    - Compressibility is however a property of FLOW and not the fluid.
- Some properties:
  - Density at a point:

$$\rho = \lim_{\Delta V \to \delta V} \frac{\Delta m}{\Delta V}$$

    - Seeing that ΔV can never equal 0, $\Delta V \to \delta V$ gives a logical meaning to the equation.

1.2. Fluid properties at a point (2)

- Some properties (continued):
  - Stress at a point:

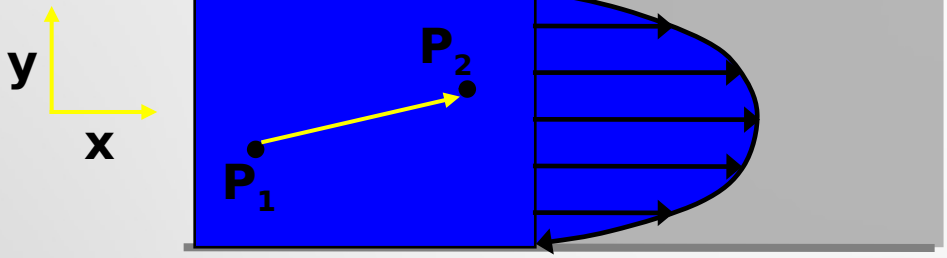
Refer to Fig 1.2 in the textbook

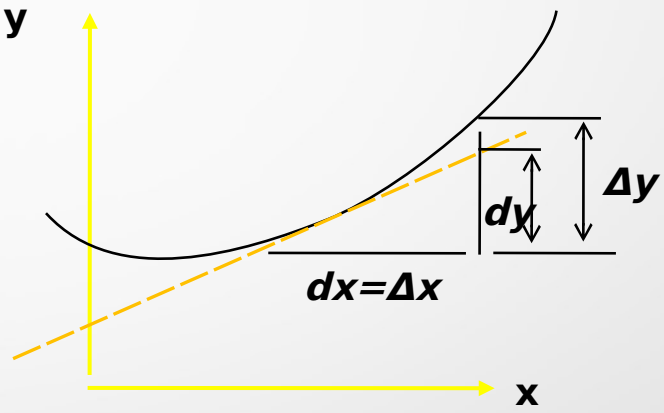
  - Forces acting on a fluid divided into 2 general groups:
    - Body Forces: (without physical contact like: gravity & electrostatic forces);
    - Surface Forces: (require physical contact like: pressure & friction).
  - Pressure at a point in a static fluid:

Refer to Fig 1.4 and derivation

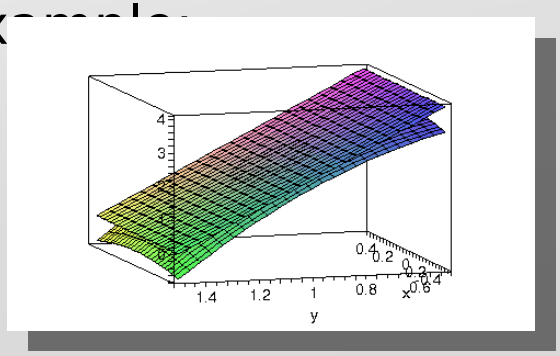
1.2.1. Point-to-point variation (1)

- The following will be evaluated for momentum transfer in a fluid:
  - Pressure, temperature, density, velocity & stress fields.



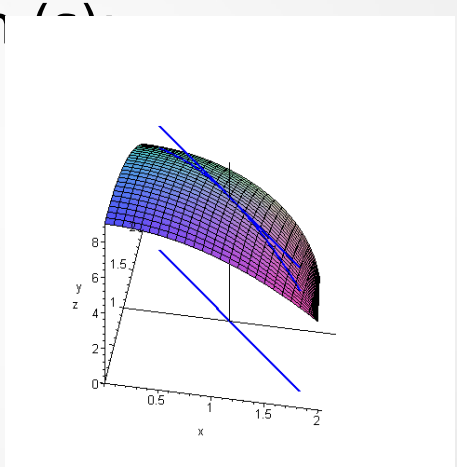


- The variation of such parameters in space between two points can be represented by PDEs for example:
  - Pressure variation in 2D-space:

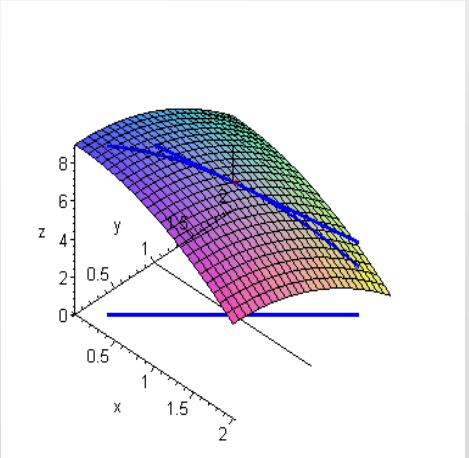


1.2.1. Point-to-point variation (2)

- Pressure variation along a specified path (a)



- Maximum pressure difference in 3-D:



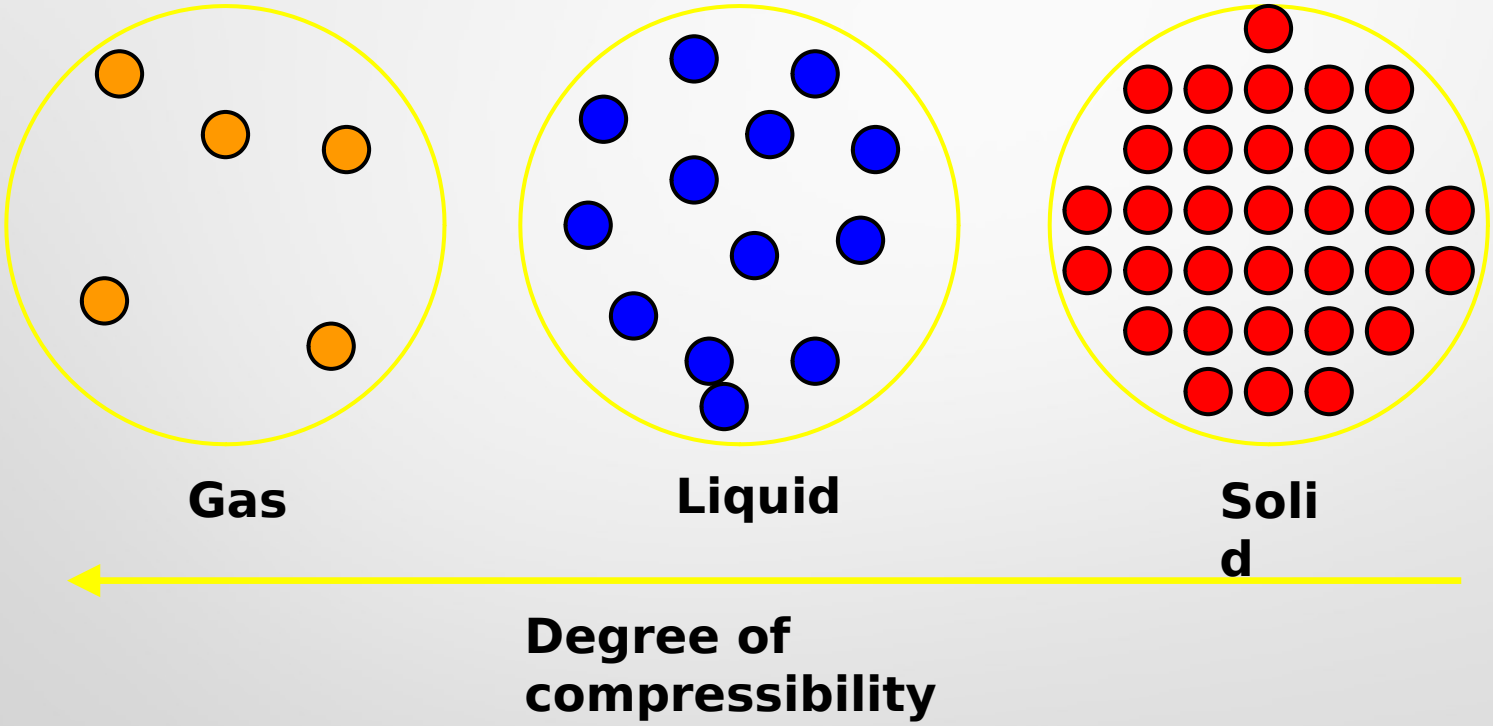
where

For more clarity revisit:
"Early transcendentials of multivariable calculus"

Be Familiar with Table 1.1 W,W,W & R - UNITS

1.3. Compressibility (1)

- Compressibility depends on varience of density.



Does density vary? YES or NO?

1.3. Compressibility (2)

- Modulus of elasticity:

Speed of sound in the fluid

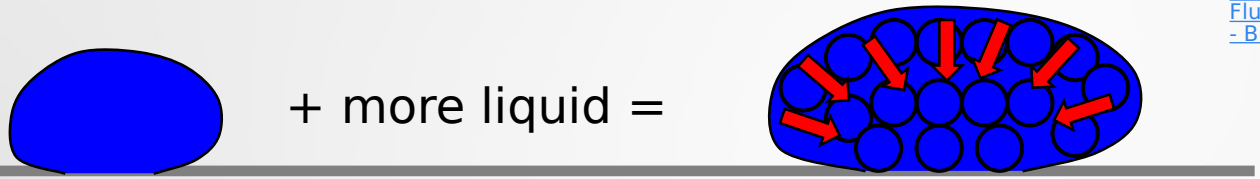
- Dimensionless parameter (Mach number) obtained using definitions of acoustic velocity & fluid velocity:

- *If M < 0.2 then gas flow is treated as incompressible.*

1.4. Surface Tension (1)

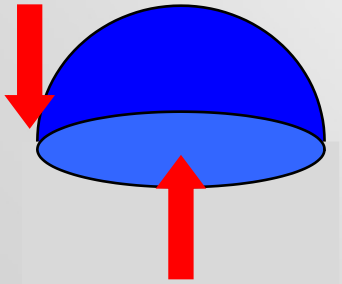
Surface Tension and Adhesion | Fluids | Physics | Khan Academy - Bing video

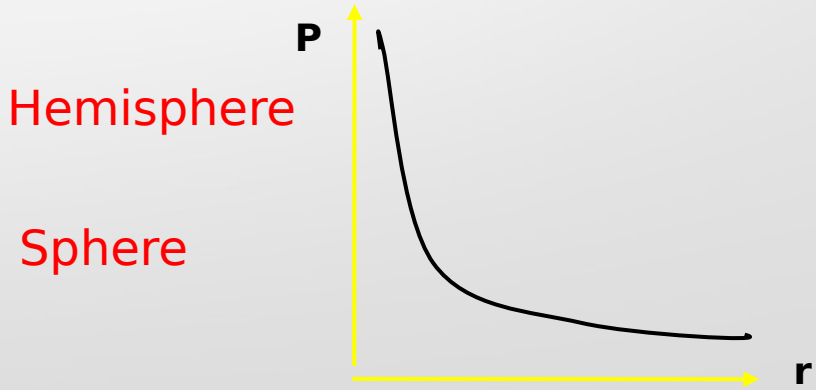
- What is surface tansion?



Refer to Table 1.2

Work done to create new surface =
Surface tension

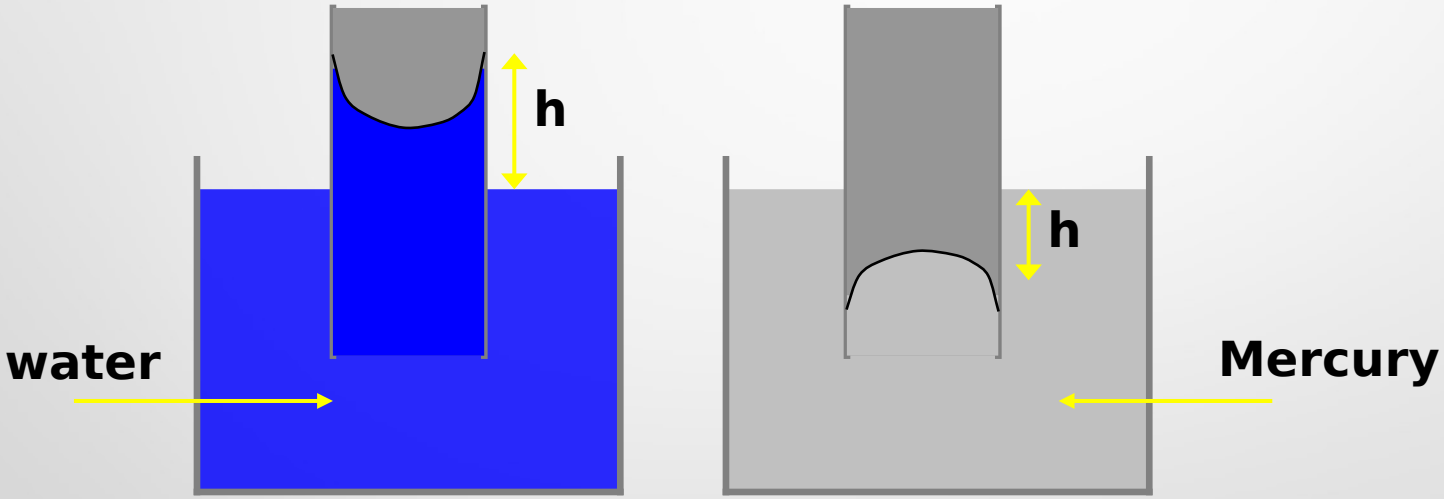




Refer to Fig 1.7

1.4. Surface Tension (2)

- Direct consequence of surface tension:
  - Capillary action



Attraction between water molecules and tube wall > attraction between water molecules at liquid surface

1.5. Fluid Statics (1)

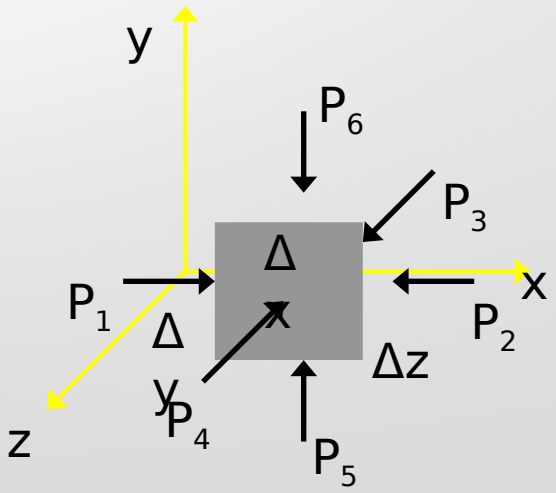
- Pressure variation in a static fluid:

Divide by volume increment:

Let the differential volume approach zero:

Thus:

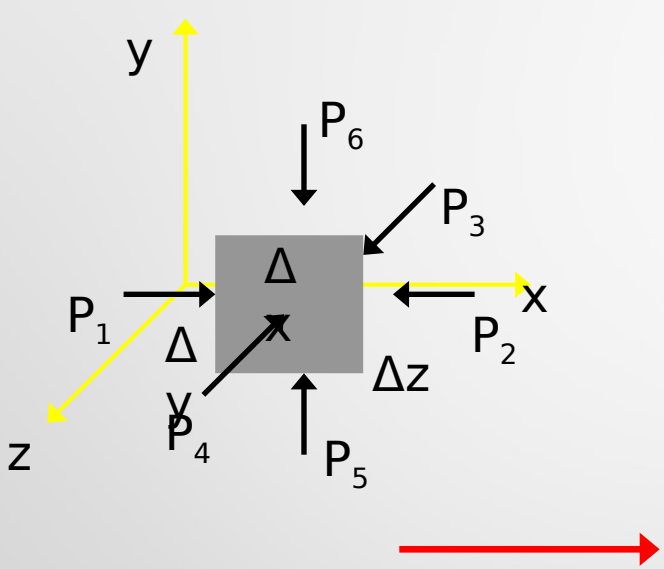
or



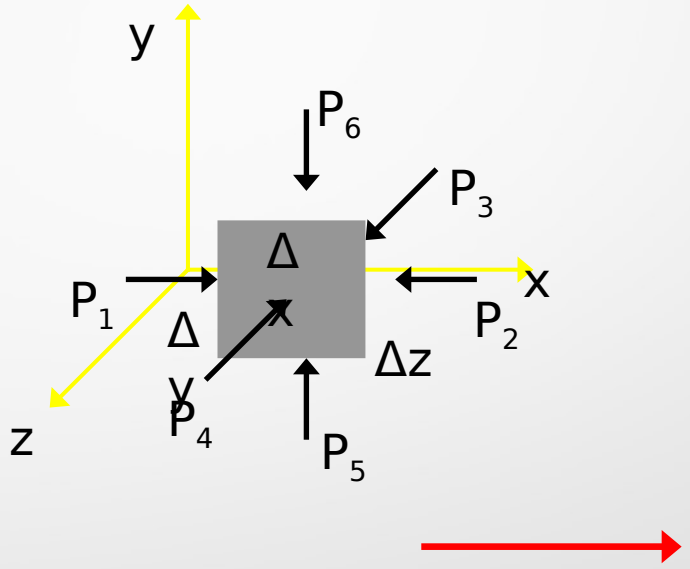
Basic Eq. for fluid statics – the max rate of change of pressure occurs in the direction of

1.5. Fluid Statics (2)

- Uniform Rectilinear Acceleration:



Inertial coordinate system

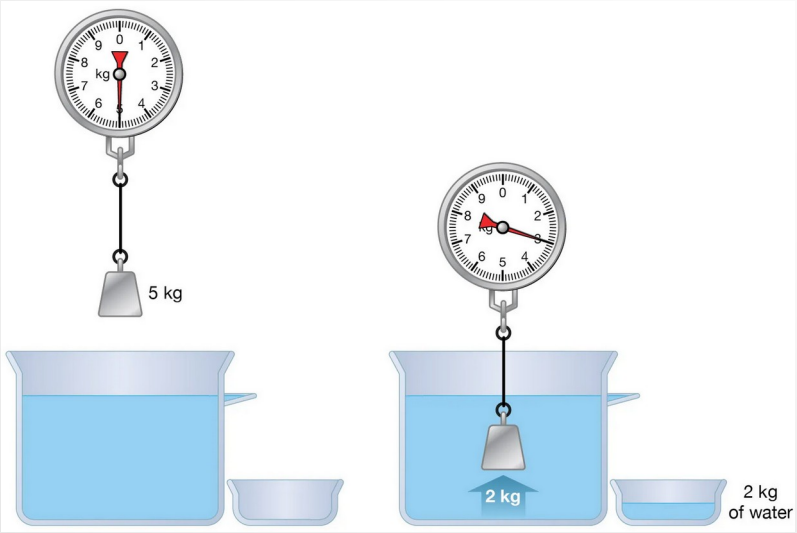


Noninertial coordinate system

See Example 1 in Chapter 2

1.5. Fluid Statics (3)

- The concept of Archimedes:

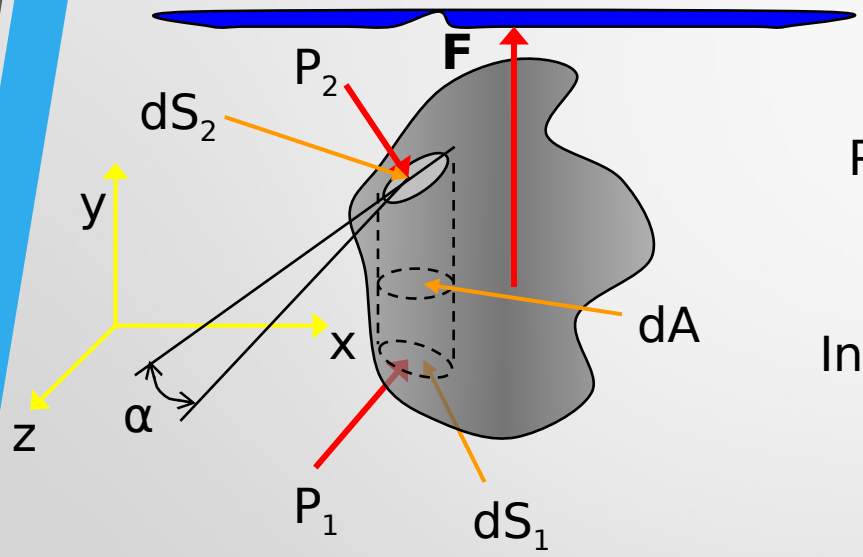


Archimedes principle states that any object, wholly or partially immersed in a fluid, experiences an upward force equal to the weight of the fluid displaced by the object. This upward force is known as buoyant force, and it explains why objects float or sink, with applications in ship design, submarines, and density measurement.

Why does a buoyant force occur?

1.5. Fluid Statics (4)

- Forces on submerged surfaces & buoyancy:



Pressure difference becomes:

Integration over the entire volume body:

Buoyant force

Weight (gravitational force)

Your work?

- Study W,W,W & R (2008) p. 1-28.
- Watch:
  - What is a fluid?

    https://www.youtube.com/watch?v=JHwlWDhYuJQ&list=PLBAcrca02tZfyGqWYSgkA-BoWzunyRhBG&index=1

  - Surface tension part 1

    https://www.youtube.com/watch?v=YdLeLvNfE-w&list=PLBAcrca02tZfyGqWYSgkA-BoWzunyRhBG&index=3

- Work through study guide: (2024) p.1-6.
  - Do concept exercises 1.1-1.4.
- Do Tutorial 1: 1.17, 1.18, 2.2, 2.15, 2.28